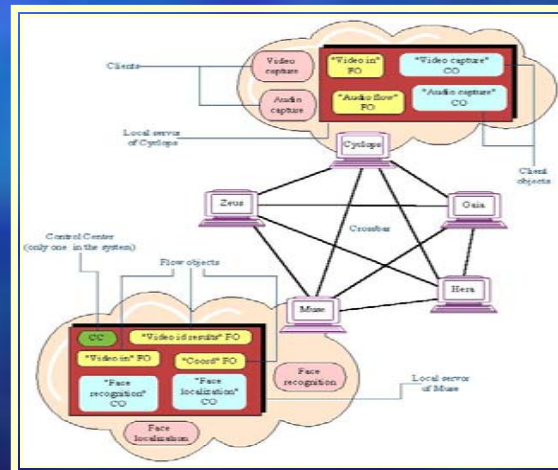
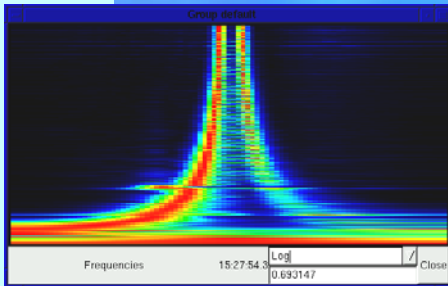


The NIST Smart Flow System: *Integrating Intelligent Systems*

NIST Information Access Division

May 1, 2001

Vincent.Stanford@NIST.Gov



Pervasive Computing Requires Broad Technological Advances

Dynamic Networking



Advanced Interfaces



Problem: Industrial and academic technology base fragmented

NIST Pervasive Computing Role

Test Beds



Reference Data & Metrics



Interoperability, conformance, & performance tests



Pervasive Computing Environment

Pervasive Devices



Information Access



Solution: Standard Measurement, interoperability, & reference data

Just A Sample of Related Efforts:

Industry Labs:

Anderson Consulting: Active environments

C5 Corporation: Adaptive Learning Smart Space

HP Research: Sensor-based computer interfaces; Appliances and Media Systems

IBM Research: Pervasive Computing; Natural Interactivity

Intel: OPEN CV; Home RF Working Group

Microsoft Research: Intelligent Environments; Easy Living

Motorola: Human Interface Laboratory

SUN Microsystems: Java/Jini; Advanced Computer Interfaces

Xerox FX Pal: Smart Media Spaces

SRI: Mediated Spaces

... More too numerous to mention

These focus on component technologies - NIST focuses on interoperability, integration, testing, and standards.

Academic Labs:

CMU: Pervasive invisible computing; Automated surveillance; Multi-modal perceptual interfaces

Georgia Tech: eClass; Aware home; Future Computing Environment group

Indiana University: Pervasive Computing Research (IPCRES)

MIT: House of the Future; Intelligent Room; Media Laboratory Gesture and Narrative Language Group; Things That Think; Oxygen; Kids Room; Smart Desks; Smart Room specialized for Business environment; Wearable Computing

Rutgers CAIP: DISCIPLE; Multimedia Information Systems Laboratory; Microphone Arrays; Multi-modal User Interaction

Stanford: Interactive Workspaces; Responsive Workbench; Project Archimedes

University of California: Profollower; User Interface Research; Audio Video Interface for Intelligent Environments

Venture Capital Conference

“Ten Pervasive Computing Companies Named "Investors' Choice" at Technologic Partners' Technology Outlook Conference.

SAN FRANCISCO, December 5, 2000—Technologic Partners announced today ... in San Francisco the ten private pervasive computing companies judged most likely to succeed. "In recent months mobile and pervasive computing has been an explosive market segment, and these companies demonstrate exceptional promise," said Richard A. Shaffer, principal of Technologic Partners.

2Wire provides technology for in-home broadband networks.

AlterEgo Networks infrastructure for wireless web content.

Atheros Communications - standards-based, wireless technology.

Entropia -Distributed computing technologies.

MobileAria Hands-free mobile Internet service platform for automobiles.

PacketVideo - Video and audio on wireless networks.

Silicon Wave - Semiconductor products and silicon tuners.

Tresidder - Mobile marketing and commerce on wireless devices.

United Devices - Distributed computing technologies.

ViaFone - Interactive mobile applications for businesses.”

Web Search Engine shows over a Million Hits

(Source: Google March 2001)

- **Smart Space - 778,000**
- **Bluetooth - 436,000**
- **Pervasive/Ubiquitous Computing - 220,000**
- **Jini - 193,000**
- **802.11 - 125,300**
- **UPnP - 100,000**
- **Dynamic Device Discovery - 76,600**
- **Home RF - 13,700**

NIST Pervasive Computing

Identify and Enhance

■ *Key Technologies:*

– *Pervasive devices:*

- Wireless protocols
- Device Discovery
- Service Discovery
- Interoperability

– *Data interface and transport*

- Sensor data transport
- Data flow standardization

– *Advanced interfaces:*

- Speech
- Speakers
- Faces
- Gestures
- Biometrics

■ *Key partners:*

– *Industry:*

- Smart Space: BBN/GTE, FX/PAL, HP, IBM, Kaiser Permanente, Bell South, SRI
- Wireless: Sun, Microsoft, Bluetooth SIG with Ericsson, IBM, Intel,

– *Government:*

- DARPA, NSF, FCC, DoD

– *Academic Labs:*

- Rutgers CAIP Center; Georgia Tech; MIT AI Lab

– *You?*

NIST Role:

NEUTRAL THIRD PARTY

“Pervasive Computing is in its infancy, requiring high risk technologies, from numerous laboratories and companies”

■ ***Collecting common reference data for industry:***

- Sensor based interfaces
- Data architecture/transport
- Service Discovery
- 2.4GHz compatibility

■ ***Developing common metrics and test tools:***

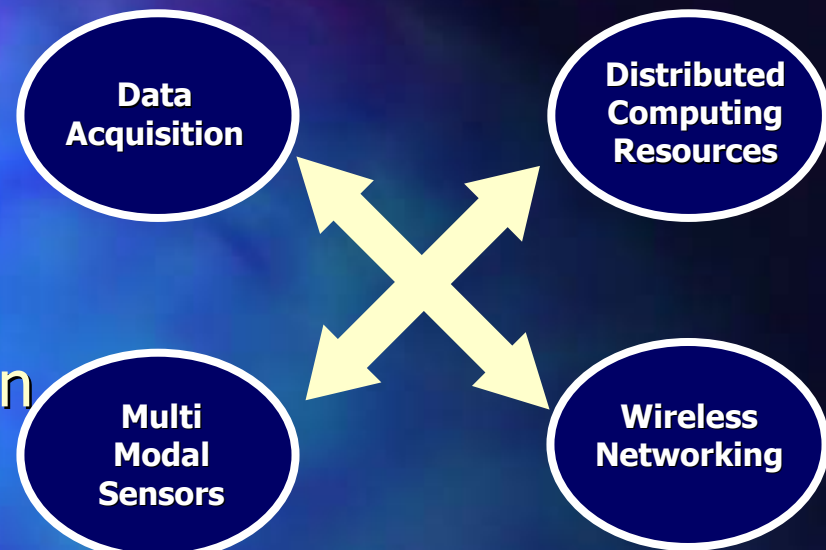
- Metrics companies need, but cannot invest in
- Data annotation systems
- impartial evaluations of systems and components
- conformance & interoperability tests

■ ***Develop Modular test beds*** for pervasive technologies

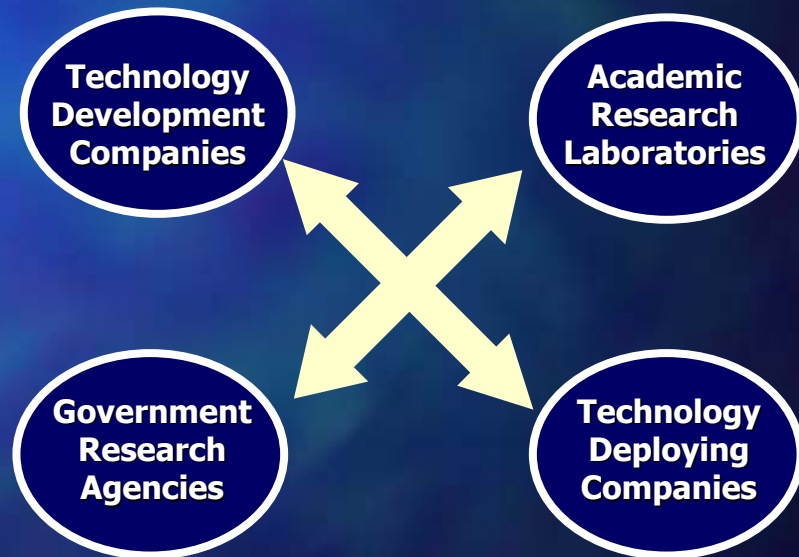
- Reference data set construction
- functional evaluation:
 - Recognition components
 - Speech
 - Speakers
 - Faces
 - Gestures
- Densely populated wireless pervasive environments
- Wireless protocol interoperability testing
- Provide unique infrastructure for data transport, interoperability, service/device discovery and testing

The NIST Smart Space Project is About Cooperation:

- **Technology** - Smart Flow open source
- **Metrics** - Array SNR algorithm
- **Standards** - Smart Flow Data Interface
- **Reference Data** - Acquisition Technology
- **Testing** - Interoperability, and compatibility
- **Partnerships** - Industrial and academic R&D laboratories



■ Technologies



■ Organizations

A Pervasive Computing Integration Challenge

■ Meeting Room Test Bed That:

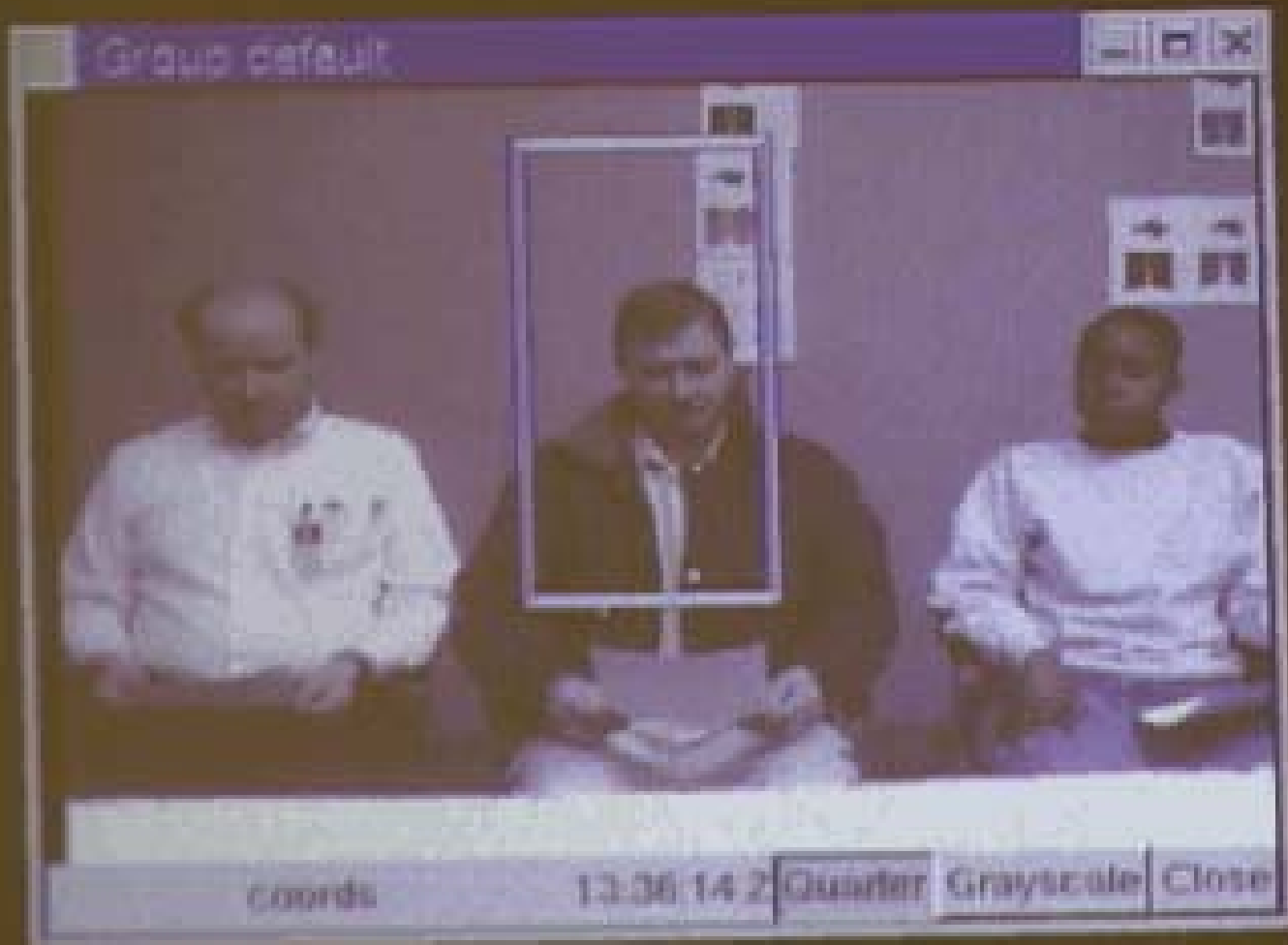
- **Takes minute and responds to commands**, depending on who speaks, what they look at, or point to...
- **Accesses information** for participants
- **Provides security** based on participant biometrics
- **Supports Service and device discovery** for pervasive computers

■ This Can't Happen Without:

- **Cooperation** - By numerous R&D Labs
- **Interoperability** - Numerous devices must play together
- **SW/HW Integration** - Sensor arrays must deliver data to numerous recognition components
- **Advances in Interface Technologies that *Sense, Recognize, Respond***

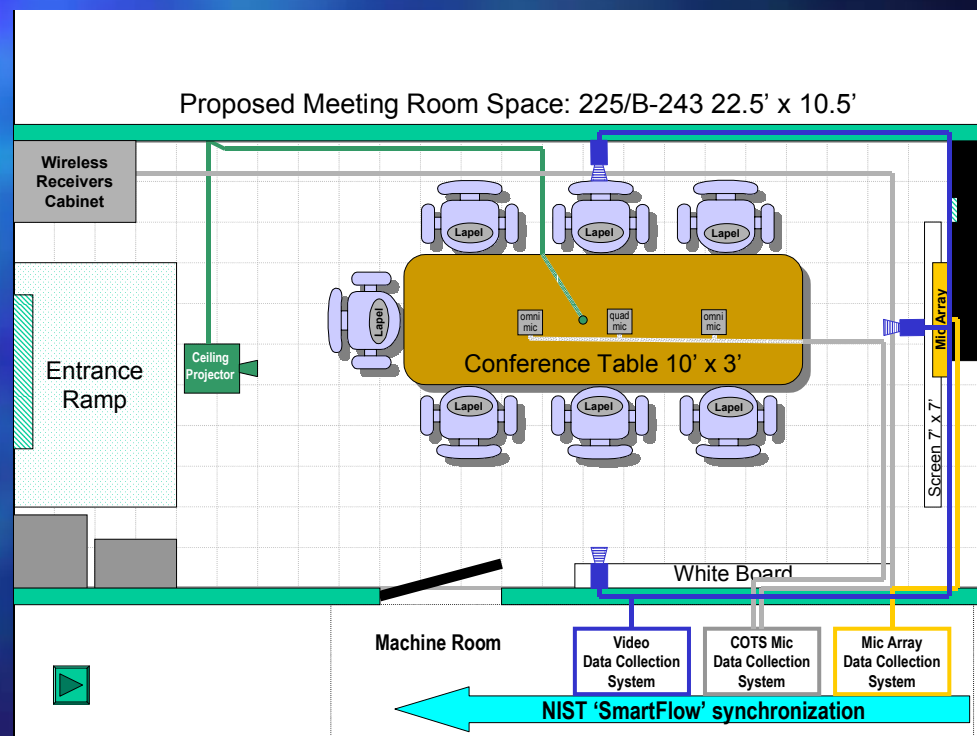
Example: Smart Flow Integration

Intel OpenCV - NIST Array



Meeting Room Project Data Collection

- ***NIST Smart Flow system*** enables multi-channel multi-modal recording and archiving of meeting room corpora
- Four Camera Views
- 200+ Microphones
 - ADAT close-talk microphones
 - Three arrays
- Creation of meeting speech corpus
- Annotation of corpus
- Cooperative work with technology providers/users

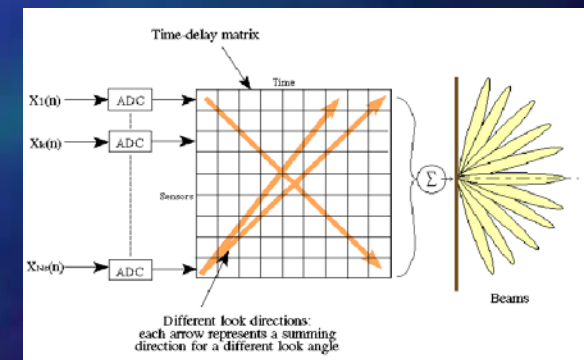
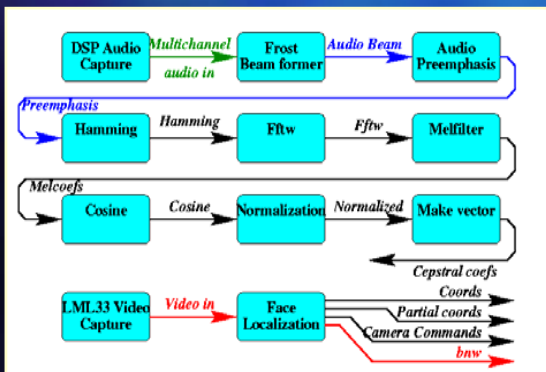
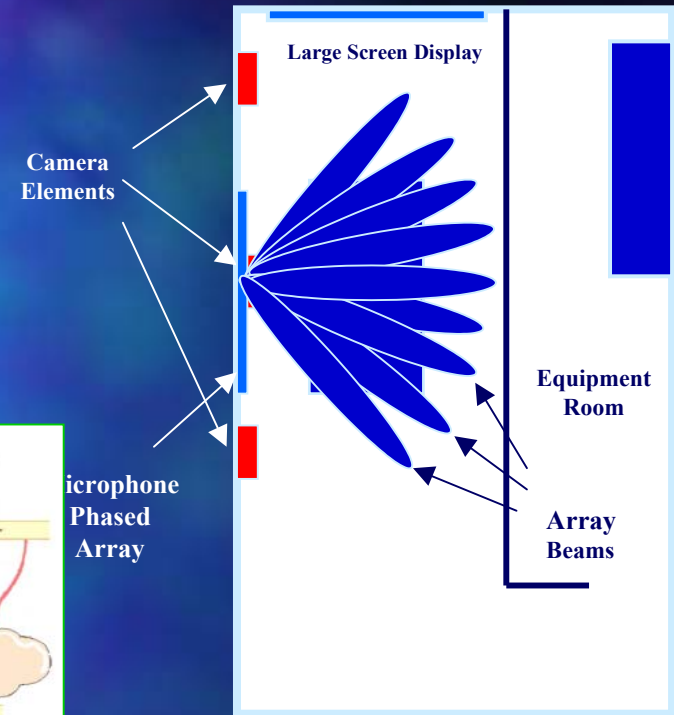
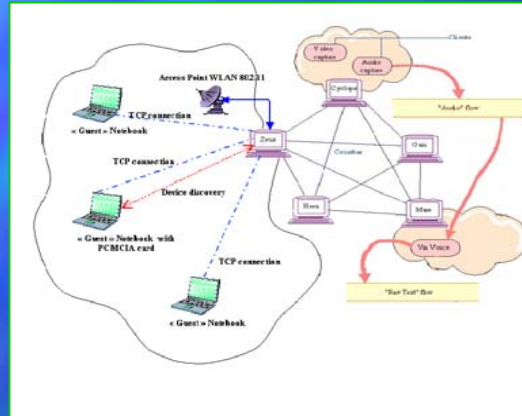


Smart Space Test Bed

- **Multi modal sensors:**
 - Microphone arrays
 - Multiple Cameras/video capture
- **Pervasive devices:**
 - Lap tops
 - Palm tops
 - Tablets
- **Multiple wireless protocols:**
 - 802.11
 - Bluetooth
 - Home RF



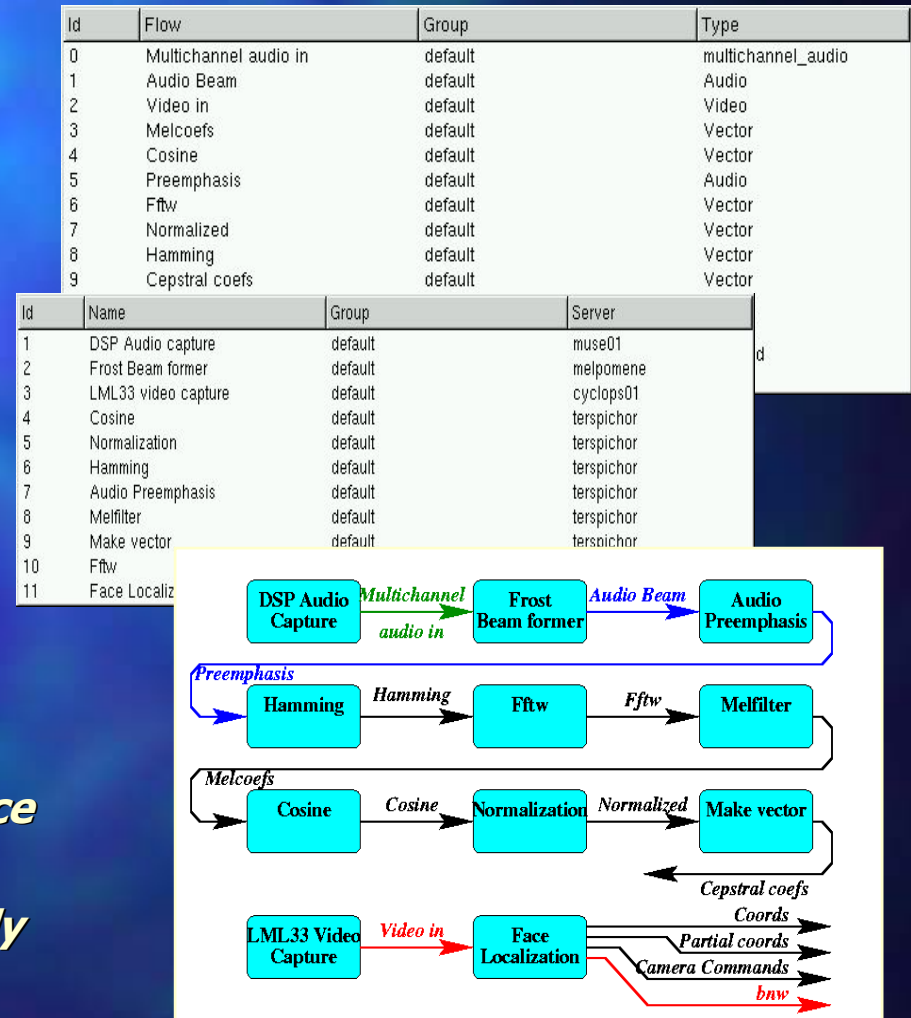
Steve Munday



The NIST Smart Flow Interoperability Standard

- Multi modal sensor arrays
- Multi-channel data collection

- Large grain data flow, for distributed processing of sensor array data
- Components and flows used by name:
 - network transparent
 - component transparent
- The system handles detail work
 - resource searching
 - data pushing
 - flow visualization interface
 - Time Tags flow buffers
- Data types: Video, Audio, Vectors, Matrices, Opaque data
- Promotes well defined, public, interface standard for component technologies
- Open Source, documentation, currently downloadable



New York Times Reports on NIST Smart Flow Users with Mk-II Array

THE NEW YORK TIMES, THURSDAY, APRIL 5, 2001

'Smart' Home Eases Elder Care

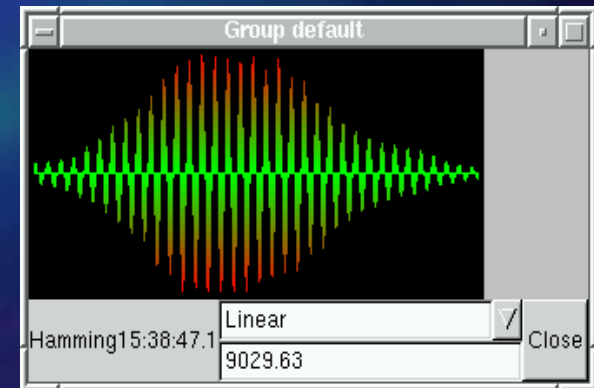
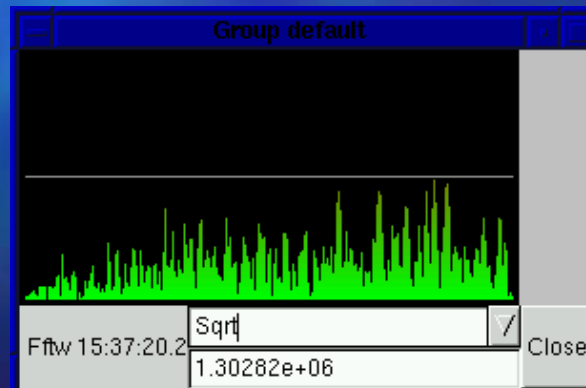
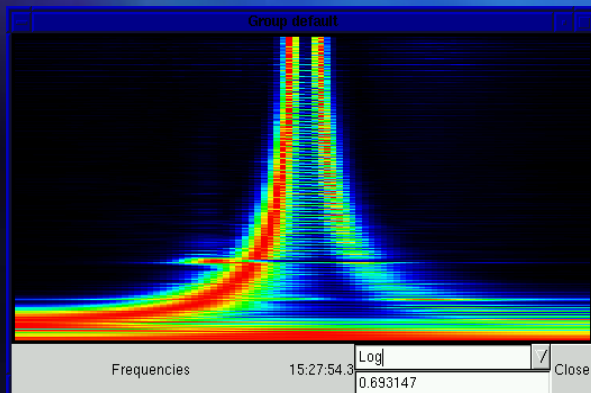
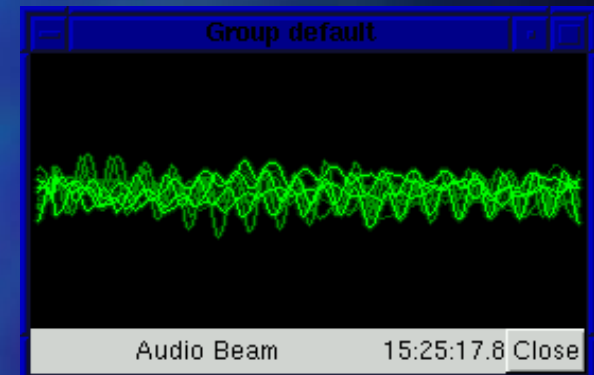
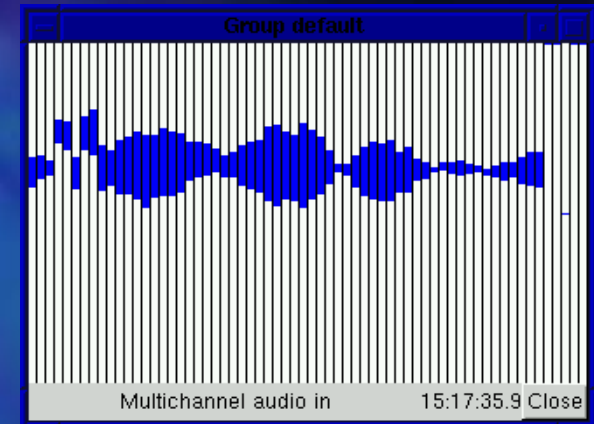


The NIST Smart Flow System Presently Contains

- **Data flow server, text and graphical control centers**
- **Audio pipelines (fft, cepstral vectors)**
- **Delay-and-sum, frost beam formers**
- **Acoustic source locator, voice/background threshold**
- **Intel OpenCV integration**
- **IBM Via Voice smart flow interface**
- **Audio capture and output, matrix, 64 channel audio, channel extractor, single channel audio, and vector input/output**
- **Novel SNR Metric**
- **MJPEG player and recorder, video capture and display**
- **LML H33 camera, IIADC 64 drivers for Linux**

Smart Flow System Display Examples

- Flow Displays for fault isolation and diagnosis
 - Multi channel audio
 - Beam formed channel
 - Cepstral pipeline
 - Short time power spectra
 - Frequency direction map

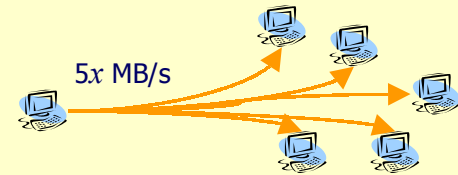
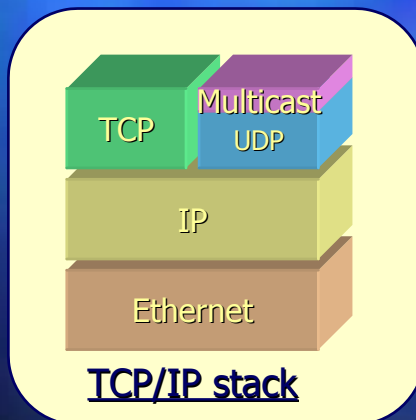


Multicast in the Smart Flow system

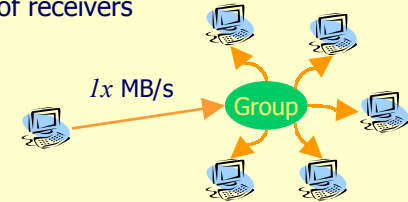
■ Requirement - Bandwidth Conservation:

- 1 to many architecture - each sender may have many receivers
- Need to save bandwidth for high volume flows
- Microphone array produces 3 megabytes per second

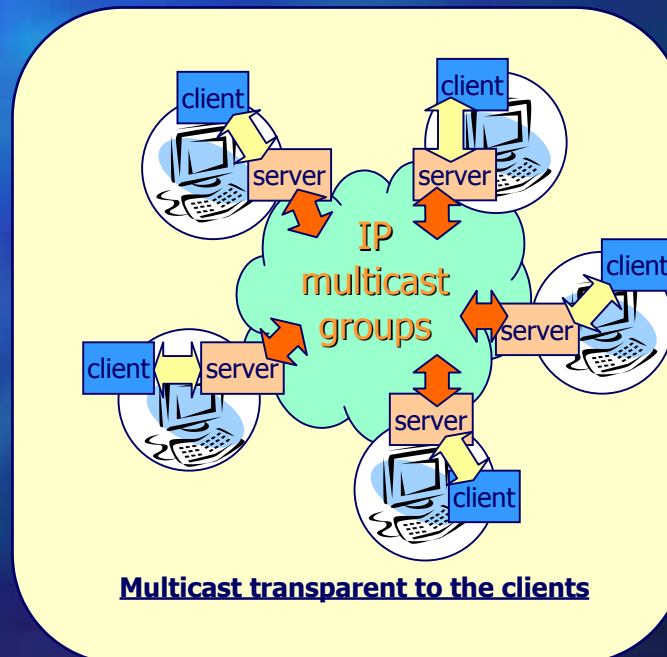
■ Solution - IP Multicast:



Without Multicast : bandwidth usage is proportional to the number of receivers



With Multicast : bandwidth usage is a constant



Smart Space Test Bed Wireless Environment

- The NIST Smart Flow test bed 2.4GHz wireless components:
 - Bluetooth
 - 802.11
 - Home RF
 - Range LAN
- Network RF component tests using Smart Space applications:
 - Concurrent applications for stress
 - Bluetooth RF level BER quality
 - Protocol conformance
 - Interoperability



THE WALL STREET JOURNAL.

TECH CENTER

January 8, 2001

Raft of New Wireless Technologies Could Lead to Airwave Gridlock

By JARED SANDBERG -
Staff Reporter of THE WALL STREET JOURNAL

“... Brace for mid-air collisions. The high-tech industry is hyping a raft of new ... Palm hand-held devices and other gadgets to the Internet and corporate networks, as well as to each other. ... But these technologies communicate in the increasingly crowded 2.4 gigahertz band of the radio spectrum, potentially clogging the airwaves...”

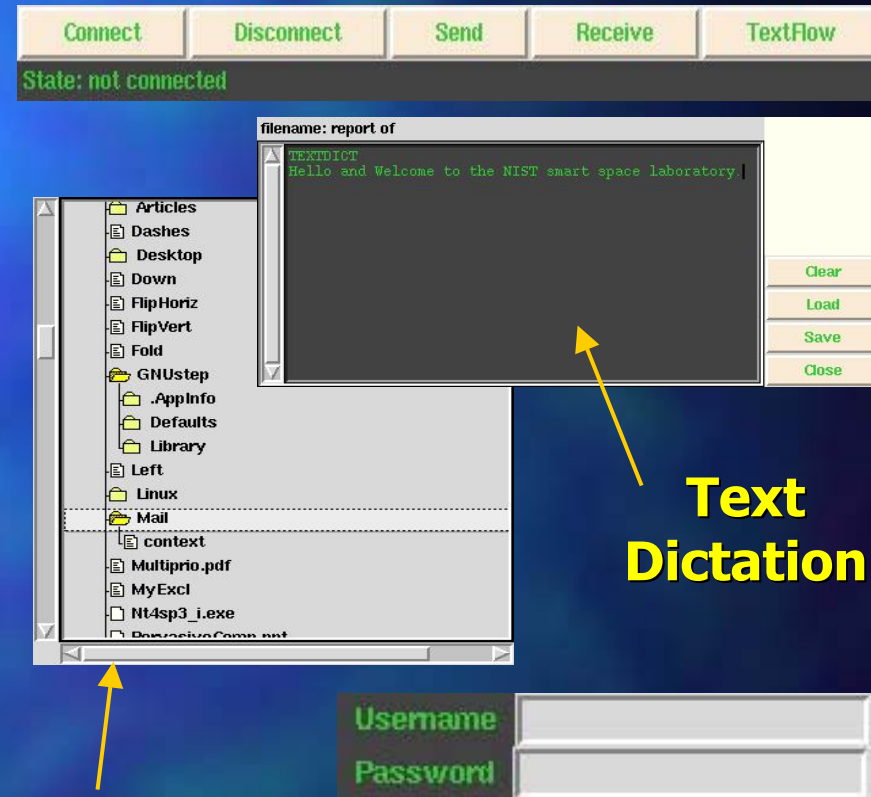


- The NIST Advanced Network Technology Division will use Smart Space test bed as a measurement lab for emerging wireless Technologies:
 - ANTD responsible for measuring tools from the physical point of view
 - IAD responsible for measuring technologies at signal, human interaction, and application levels

Discovery of Pervasive Device by Smart Space

Command Center

- Pervasive interface for meeting minutes:
 - Device discovery
 - Authentication
 - Data transfer
 - Transcribed text
- Wireless Communications Tools such as:
 - Proxim RangeLAN2 (2Mbit/s)
 - CISCO Aironet (11Mbit/s)
 - BlueTooth PCMCIA cards (2Mbs)
 - Intel Home RF
- Communication Tool:
 - *Smart Flow Infrastructure*
 - *Device Discovery*



Text Dictation

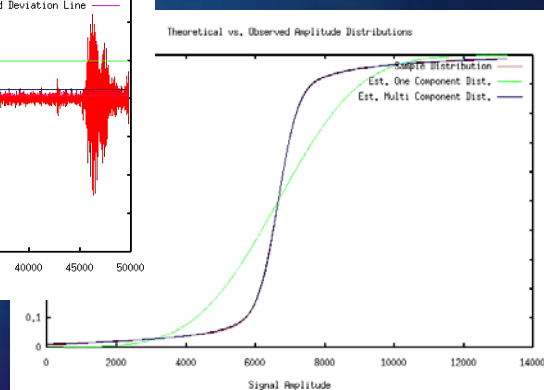
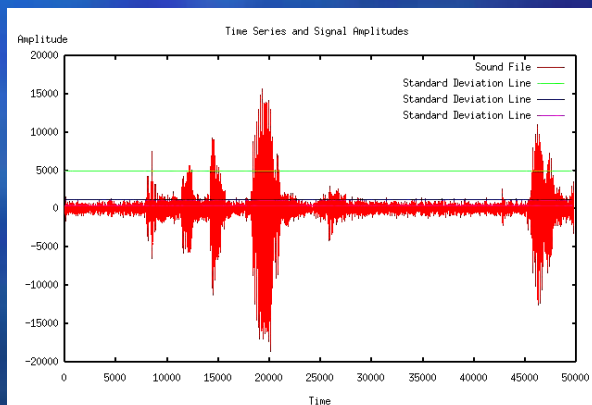
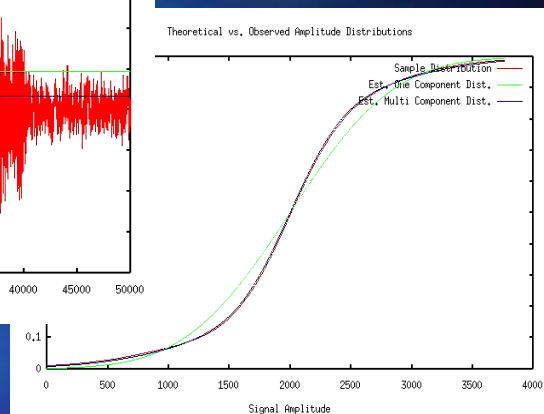
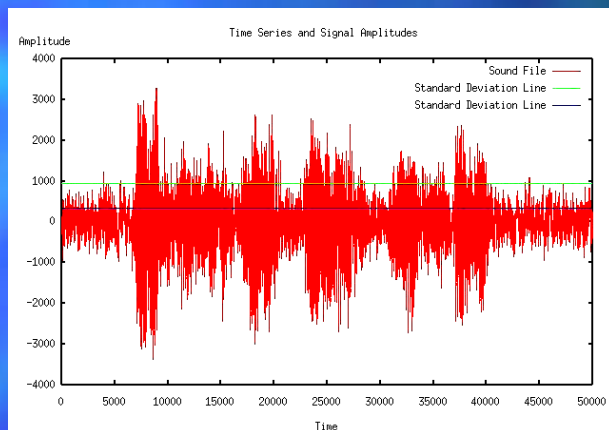
File Transfer

Authentication

An SNR Metric for Speech In Noise

How Much do Algorithms Help?

- We never get to see speech without noise
- Zero mean Gaussian Mixture components:
 - Background
 - Unvoiced speech
 - Voiced speech
- EM Estimation of Mixture, high speed open source tool available
- Example:
 - Single microphone SNR=9dB
 - Beam former SNR=21dB
 - 12dB improvement



What Have We Done So Far?

Summary

- **Developed and documented the NIST Smart Flow System (NSFS)**
- **Deployed Nist Smart Space Research Web Site**
- **All digital Mk-II array data acquisition and beam forming Systems**
- **Acoustic source locator based on beam former**
- **Integrated components:**
 - **IBM Speech Recognition**
 - **Intel OpenCV Face Recognition**
 - **Wireless networking components**
- **Multicast TCP/UDP data transmission to address bandwidth limitations for high data rate sensor arrays**
- **Opened cooperative efforts using NSFS Open Source with Premier R&D Laboratories:**
 - **Rutgers CAIP Center**
 - **MIT AI Laboratory**
 - **Georgia Tech Aware Home**
 - **Bell South**
 - **Kaiser Permanente Research**
- **Developed novel SNR measurement tool to evaluate speech SNR**

What's Next?

Summary

- **Meeting Room:**
 - Data gathering infrastructure
 - Some automatic annotation
- **Integrate additional industrial technologies:**
 - Speaker identification
 - Gesture recognition
 - Information retrieval
- **Compatibility/performance testing of 2.4GHz band wireless protocols:**
 - 802.11
 - Bluetooth
 - Range LAN
 - Home RF
- **Expand the Industrial Partners group**
- **Deploy Smart Flow system to more R&D organizations, and improve it using open source model**
- **Move towards establishing Smart Flow system interoperability standards working group**
- **Integrate more technologies and provide multi modal, multi sensor reference data, and compatibility tests in cooperation with other NIST groups**

The NIST Smart Space Project

Summary

■ *Reduce barriers to R&D entry:*

- Reference implementation of Smart Flow saves man years at startup
- Common open source base components:
 - Data acquisition
 - Audio
 - Video
 - Data Archiving
 - Signal processing
 - Beam forming
 - **Performance metrics**

■ *Create entrepreneurial opportunity:*

- Standardized data transport layer allows cooperative development projects
- Interfaces to other industrial components can allow new combinations of technologies, sensor fusion and recognition technologies.

■ **Vincent.Stanford@NIST.Gov**